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Hazard Screening Process Used in the Phased Update of Facility Safety Documentation

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Abstract

Several world events of significant consequence (chemical releases, natural-phenomena-induced events, nuclear reactor mishaps) have influenced the U.S. Department of Energy (DOE) to impose on its operating contractors, new, more stringent standards of technical rigor and completeness for safety analysis of its facilities. These new standards require greater understanding and more complete documentation of the significant risks involved in the operation of potentially hazardous facilities.

To address the need to more rigorously analyze and prepare safety documentation for hundreds of operating facilities in a timely manner, Martin Marietta Energy Systems, Inc., in conjunction with DOE, developed a multi-phased approach to updating the safety analyses. This phased approach included hazard-based prioritization of analysis efforts to permit a higher proportion of safety documentation resources to be applied to the larger magnitude hazards at the earliest opportunity. Completion of a well documented hazard screening effort was an essential part of the process to classify hazard levels, to prioritize completion of further analysis, and to provide risk reduction plans for processes, procedures or equipment that presented undue risk to people, either onsite or offsite.

A Preliminary Hazard Screening process was used to screen out facilities or processes that were obviously benign. Those not eliminated were divided into systems and analyzed by itemizing the hazards and identifying possible initiating events through the use of a modified Hazard and Operability (HAZOP) technique. Accident scenarios were developed to determine the bounding cases, and conservative consequence calculations were performed for those bounding cases. The results of the consequence calculations, in terms of predicted human health effects were compared to screening tables developed to determine initial hazard classification.

Hazard consequence prediction methodology and hazard classification criteria are introduced with examples of how the screening results have been used.

Introduction

The facilities managed by Martin Marietta Energy Systems, Inc., (Energy Systems) for the Department of Energy (DOE) have research and production missions that are important to our country's energy supply and national security.

Many of the facilities were built 30 or 40 years ago, long before well-documented safety analysis reports (SARs) were required. Fortunately Energy Systems' facilities have operated without serious incident in the past. However, as a result of domestic and international events that have occurred over the past several years (chemical releases, natural-phenomena-induced events, nuclear reactor mishaps, and mechanical failures), DOE has taken responsive actions to impose more stringent standards of technical rigor and completeness for the safety analyses of its operating facilities.

Phased Approach for Updating Safety Analysis Reports

In late 1989, DOE and Energy Systems agreed that up-to-date SARs would be prepared for all DOE facilities managed by Energy Systems. Each potentially hazardous facility would be thoroughly analyzed using currently accepted principles and standards, and documented in a manner that would provide future users with confidence that the facility is operating without imposing an undue risk to employees or to the general public.

The task of creating up-to-date safety analysis for the large number of "moderate" and "low" hazard facilities managed by Energy Systems poses a number of difficult challenges: the correct identification and use of resources, the methodology of documenting new or modifications to existing facilities during the update process, and the assurance that the system is applicable to all parts of Martin Marietta Energy Systems, Inc. To cope with these challenges, the update of the SARs is being accomplished through a multi-phase program. This program includes the reevaluation of existing facilities, relative ranking of hazard levels, making immediate operational changes when necessary for safety, and proceeding with a systematic hazard-prioritized effort to perform and document a rigorous, detailed analyses over the next several years. Implementation and guidance documents used in this program were created largely by those who would be users of the guidance. The program tasks are accomplished by teams consisting of safety analysts, operations and management personnel in recognition of the fact that one of the keys to enhancing facility safety is the development of a thorough knowledge and appreciation of the potential hazards and risks involved.

Each phase of the SAR Update Program is designed to develop parts of a modern, comprehensive SAR that are useful while the remainder of the SAR is being developed. The program is designed to strengthen the bases for safe operation of the subject facilities at each phase, providing information to support other safety assurance and configuration management programs and to allocate resources to successive phases according to the importance of the safety issues being analyzed.

Phase 0 was designed to qualitatively evaluate ongoing operation for those facilities judged by line and plant management to pose potentially significant hazards. It concluded with recommendations for actions that would reduce the risk of facility operation. In cases where the risk was deemed unacceptable, operations were temporarily suspended until the operating risk was reduced.

Phase I and IA involved detailed hazard screening procedures for all facilities. Technical or Operational Safety Requirements (TSR or OSR) were examined and updated for many of the facilities, using the qualitative bases available at this stage of the upgrade effort. The analyses and documentation completed during this phase were used not only to prioritize facility analyses during the next phase of the SAR Update Program but, for several facilities, resulted in additional risk reduction actions.

Phase II, which is currently in progress, involves complete accident analysis for those facilities ranked as having a potentially moderate hazard level based on the conservative screening methods of Phase I. This in-depth analysis of the estimated accident scenario frequencies and consequences will be incorporated in a Facility Safety Evaluation (FSE), an abbreviated safety analysis document, along with condensed facility and process descriptions. Quantitative bases will be developed for OSRs and TSRs.

Phase III will include evaluation of those facilities and elements not evaluated in Phase II, as well as the generation of the balance of sections specified by DOE for a complete FSAR.

<u>Hazard Screening Process</u>

Energy Systems has developed a screening process to classify facilities according to their potential to harm the health and safety of the public and the employees. More than 2000 facilities were subject to study in the preliminary hazard screening done in Phase I of the program. A hazard is defined as a material, energy source, or operation that has the potential to cause injury or illness in human beings. The four general hazard classifications are high (significant potential consequences to the general public) moderate (significant potential consequences to onsite personnel), low (significant potential consequences to those operators in the immediate vicinity) and generally accepted (no harm beyond that the public is traditionally willing to accept). Further analysis is then concentrated first on those facilities posing the more significant hazard potential.

The basic purpose of hazard screening is to group processes and facilities according to the magnitude of their hazards so as to determine the need for and extent of follow on safety analysis. Results of the screening process can also be used for early identification of the need for additional accident prevention or mitigation strategies.

The first step of the hazard screening process involves a sorting operation to screen out the most benign facilities and processes. This preliminary hazard screening (PHS) consists of filling out a checklist of hazard types and a quantitative measure of each hazard. If the maximum expected value of a hazard exceeds the quantitative measure value, then the subject facility or process is retained for screening of potential consequences from the hazard. If the maximum anticipated value of the hazard (quantity of material, temperature, pressure, etc) is below the screening limit, all findings are thoroughly documented and the facility or process is eliminated from further analysis until later in the overall update program. Any proposed change to the facility or process must be evaluated against this PHS document to insure the change would not increase the hazard potential.

Facilities and processes not eliminated by PHS are divided into systems that perform a specific function so that hazards can be characterized and quantified, and possible initiating events for hazard realization can be identified using a modified Hazard and Operability (HAZOP) technique. The modified HAZOP is a structured approach for identifying specific failures (i.e. initiating events) that could cause safety problems due to the hazards involved. Unlike "normal" HAZOP studies, these are focused on safety and not on operational issues. The initiating events are required to be physically possible but no quantified determination of "credibility" is required. With justification those initiating events qualitatively judged to have to an annual frequency of less than 10^{-6} can be eliminated from further review. Accident scenarios are then developed to determine the bounding cases, and potential consequences are conservatively calculated for those bounding cases.

In the determination of potential accident consequences, credit is not taken for active or passive mitigation. The operational mode of a system or component is taken to be the mode which would result in the worst potential consequences. For example, the offsite consequences might be worse for the case in which the building ventilation system is functioning, while the consequences inside the building would be worse if there were no forced ventilation. Calculations would then be completed assuming no ventilation for the indoor case to determine consequences to the operators, and again assuming functioning ventilation for the offsite case.

<u>Calculation of Potential Consequences</u>

After identifying potential hazards and postulating accident scenarios, "first pass" analyses are used to indicate a preliminary hazard rank by employing relatively simple, but conservative, methods to estimate the consequences of the hazards. The purpose of the suggested methods is to avoid prolonged calculations at this early stage of the hazard analysis and not to force a standardized procedure. If the use of these methods produce results that conflict with readily available information, alternative methods should be employed even at this early stage.

Most of the postulated Energy Systems accident scenarios result in the release of some toxic substance, the transport of this substance to receptors (people), and the consequences of people inhaling this substance. The substance may be radioactive, chemically toxic, and/or carcinogenic. Other postulated scenarios include the accidental exposure of personnel to radiation from nuclear criticality events and injuries due to explosions. The "first pass" analyses are used to decide whether additional analyses using more detailed (usually less conservative) methods are needed.

All analyses of releases of toxic substances involve three basic elements: (1) determining the amount and characteristics of the material released and available for transport (source term); (2) determining how much of the released material reaches humans (transport); and (3) estimating the physiological effects humans would experience from breathing the toxic substance ("dose-consequence analysis").

Two types of accidental releases are considered: (1) an instantaneous release of some fraction of the amount of material at risk and (2) a constant, steady release rate over a period of time. An instantaneous release is usually the more conservative approach and requires the least definition. An upper-bound, finite release rate (if one can be estimated) will generally be less conservative and more realistic. If enough information is available, procedures given by Ayer, et al (1988, Chapter 4) can be used to estimate the amount of released material that becomes airborne and is thus available to be inhaled. If not, all released material should be assumed to become airborne (extremely conservative) or fractions based on engineering judgement and experience should be used.

If the release takes place within a relatively small enclosure (less than about 1000 cubic meters), the close-in concentration of the airborne material can be approximated by assuming the material is instantaneously mixed with the volume of air within this enclosure. It is assumed that close-in personnel are exposed to this concentration during the time it takes them to walk out of this volume (typically at a rate of 1.5 m/s). For all other situations and large distances, the concentrations and concentration-time integrals are estimated with simple atmospheric dispersion models (e.g., Slade 1968, p 403 to 404). These models use published values of atmospheric dispersion coefficients (e.g., Hanna et. al., 1982, Table 4.5, p 30) for large distances and values based on turbulent diffusion theory for close-in distances. The models assume the receptor (a person's nose) is directly downwind of the release and at, or close to, ground level. The models also assume that the exposure period for instantaneous releases is the entire time that it takes for the cloud to pass by. For longer release durations, the exposure time is the time required to alert and evacuate people which is typically 30 minutes or longer.

Consequences due to releases of toxic substances are related to concentrations and concentration-time integrals calculated using the above methods. Concentration-time integrals are calculated for the entire period of the exposure while concentrations are time-weighted (usually, 5 minutes) averages over a time period selected to give the highest average.

Radiation associated with a nuclear criticality event arises from three sources: (1) prompt gamma rays and neutrons from the fission process itself, (2) radiation from the radioactive decay of fission products produced by the reaction, and 3) radiation from the radioactive decay of materials surrounding the reaction that have been activated by neutrons.

The prompt radiation is traditionally viewed as the most significant because, in the first pulse of an accident, there are no actions that an individual can take to limit the dose received. Also, the estimation of potential radiation doses to individuals as a result of fission product transport is not readily adaptable as a simple hazard screening method. Because of these two factors, the consequences of a criticality accident predicted by a conservative prompt dose calculation were used as the initial hazard screening of the facility. In most instances, facilities where a criticality was possible were assumed to involve at least a moderate hazard category, which automatically indicated the need for further detailed analysis during subsequent phases of the update program. Conservative fission yields are used with prompt neutron and gamma dose equations to calculate the prompt radiation dose onsite for hazard screening. This prompt dose alone is used to estimate the onsite health effect consequences of a nuclear criticality accident for the purpose of recommending a hazard classification level for the facility.

Consequence predictions for explosions are based on the blast pressure and missile range resulting from the explosion. TM 5-1300 (1969) presents methods for estimating the blast pressure and missile velocity resulting from explosions of TNT. These methods are applied to other explosives when expressed in terms of their TNT equivalence. The peak positive incident pressure, resulting from the surface explosion of a hemispherical charge of TNT in air at sea level and ignoring any shielding that might absorb part of the explosive force, was chosen as a measure of the blast pressure. A plot of this pressure (and many other quantities resulting from such an explosion) is given in TM 5-1300 (1969, Figure 4-12, p 4-8) as a function of the scaled distance from the explosion and the equivalent weight of TNT. The maximum missile velocity for a cylindrical casing can be estimated from an expression given in TM 5-1300 (1969, Equation 4-10, p 4-66). The maximum range occurs with missiles directed 45 degrees from the horizontal having this initial velocity.

In general, the guidelines provided in Table 1 are used to classify the consequences of exposure to the various hazards as causing negligible, reversible, or irreversible human health effects. The exposure levels assumed to cause these health effects are estimates intended for hazard screening purposes only. They are considered adequate for grouping the facilities into the different hazard classifications but no claim is made as to their adequacy or appropriateness for other purposes. When a value is calculated for an exposure to a hazardous material, it does not imply that the exposure is expected to occur or, if it did, that it would be acceptable. Once the number of exposed people and the relative severity of their health effects have been estimated, screening tables and additional qualitative and special considerations are used to determine the initial hazard classification for a facility. This hazard classification is used to determine when, and with what level of priority, the next phase of accident analysis will be required for the facility. Observations made during hazard identification, accident scenario development and consequence estimation efforts may result in risk reduction recommendations.

Table 1 Health Effect/Exposure Level Guidelines for Hazard Screening

TYPE of EFFECT	IRREVERSIBLE Health Effect Level	REVERSIBLE Health Effect Level	NEGLIGIBLE Health Effect Level
Chemical	Concentration $\geq$ 1.0 x IDLH	0.1 x IDLH $\leq$ concentration < 1.0 x IDLH	Concentration < 0.1 x IDLH
Radiological	> 1 sievert (100 rem)	0.1 - 1 sievert (10 - 100 rem)	< 0.1 sievert (10 rem)
Pressure	> 5 psi (peak positive incident pressure from blast)	0.5 - 5 psi	< 0.5 psi

During the hazard identification and consequence prediction efforts, many actions to reduce operating risk were recommended and implemented. Hazardous chemical inventories were reduced in several laboratory and chemical process areas after conservative consequence calculations indicated there was a potential for significant human health impact in the event of a fire or other initiating event which might cause the release of the entire inventory. Combustible wooden pallets and containers used in warehouse areas were painted with fire-retardant intumescent paint to reduce the risk of a major material release due to fire. After recognition of potentially hazardous conditions by the multi-discipline evaluation teams, many of the recommended risk reductions were easily accomplished with little operational impact and at very low cost.

Conclusions

Two and a half years into the phased upgrade effort there is a much more widespread understanding of the variety and complexity of the operations conducted at these DOE facilities, and of the hazards involved in them. Several equipment and operational changes have been initiated as a result of the early team efforts. We expect to continue to make improvements as we continue the analyses over the next several years until, in the end, we have complete and useful SAR documents that will not only provide confidence in the safety of our facilities but serve as a valuable reference for operation, engineering, management and review purposes.

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